Chapter 9: Industry

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Executive Summary

The industrial sector is extremely diverse and involves a wide range of activities. Aggregate energy use and emissions depend on the structure of industry, and the energy and carbon intensity of each of the activities. The structure of industry may depend on the development of the economy, as well as factors like resource availability and historical factors. In 1995, industry accounted for 41% (133 EJ[1]) of global energy use and up to 43% of global CO_2 emissions. Besides CO_2 industry also emits various other GHGs. Although the efficiency of industrial processes has increased greatly during the past decades, energy efficiency improvements remain the major opportunity to reduce CO_2 emissions. Potentials for efficiency improvement and emission reduction are found in all processes and sectors. In the short term, energy efficiency improvement is the major GHG reduction measure. Fundamentally new process schemes, resource efficiency, substitution of materials, changes in design and manufacture of products resulting in less material use and

[1] 1 EJ = 10^{18} Joules.

increased recycling can lead to substantial reductions in GHG emissions. Future reductions in GHG emissions are technologically feasible for the industrial sector of OECD countries if technologies comparable to that of efficient industrial facilities are adopted during stock turnover. For Annex I countries with economies in transition (CEITs), GHG reducing options are intimately tied to the economic redevelopment choices and the form that industrial restructuring takes. In developing countries large potentials for adoption of energy efficient technologies exist as the role of industry is expanding in the economy.

In industry, GHG emission reduction is often the result of investments in modern equipment, stressing the attention to sound and environmentally benign investment policies. Industrialisation may affect the environment adversely, stressing the need for the transfer of clean technologies to developing countries. Technology transfer is a process involving assessment, agreement, implementation, evaluation and adaptation, and repetition. Institutional barriers and policies influence the transaction process, as well as the efficiency of the transfer process. Developing countries suffer from all barriers that inhibit technology transfer in industrialised countries plus a multitude of other problems. Investments in industrial technology (i.e. hardware and software) are dominated by the private sector. Foreign direct investment is increasing, although concentrated on a small number of rapidly industrialising countries. These countries may impact regional industrial development patterns, as seen in Southeast Asia. Private investment in other developing regions is still limited, although increasing. Public funding (in industrialised and developing countries) for technology development and transfer, although still important, is decreasing. Funding for science and technology development is important to support industrial development, especially in developing countries. Public funding in the industrial sector, although small in comparison to private funding, remains important.

It is essential that policies provide a clear framework for technology transfer. An effective process for technology transfer will require interactivity between various users, producers and developers of technology. The variety of stakeholders makes it necessary to have a clear policy framework as part of an industrial policy for technology transfer and cooperation, both for a technology donor and recipient or user. Such a framework may include environmental, energy, (international) trade, taxation and patent legislation, as well as a variety of well-aimed incentives. Policymakers are responsible for developing such a comprehensive framework. The interactive and dynamic character of technology transfer stresses the need for innovative and flexible approaches, through partnerships between various stakeholders, including public-private partnerships. There is a strong need to develop the public and private capacities to assess and select technologies, in particular for state owned and small and medium sized industries. Stakeholders (policymakers, private investors, financing institutions) in developing countries have even more difficult access to technology information, stressing the need for a clearinghouse of information on climate change abatement technology, well integrated in the policy framework. To be successful, long-term support for capacity building is essential, stressing the need for public support and cooperation of technology suppliers and users.

Adaptation of technology to local conditions is essential, but practices vary widely. Countries that spend on average more on adaptation seem to be more successful in technology transfer. As countries industrialise the technological capabilities increase rapidly, accelerating the speed of technology diffusion and development, and demonstrating that successful technology transfer includes transfer of technological capabilities.

9.1 Introduction

The industrial sector is extremely diverse and involves a wide range of activities including the extraction of natural resources, conversion into raw materials, and manufacture of finished products. We define the industrial sector as industry including the minerals processing industries. The sub-sectors that account for roughly 45% of all industrial energy consumption are: iron and steel, chemicals, petroleum refining, pulp and paper, and cement. These industries are generally concerned with the transformation of raw material inputs (e.g. iron ore, crude oil, wood) into usable materials and products for an economy. Due to the wide variety in activities, energy demand and GHG emissions vary widely. Hence, the aggregate energy use and emissions depend on the structure (or specific set of activities) of industry, and the energy and carbon intensity of each of the activities. The structure of industry may depend on the phase of the economy, as well as many other factors like resource and technology availability as well as historical factors.

In 1995 industry accounted for 41% (131 EJ) (Price *et al.*, 1998) of global energy use and up to 47% of global CO_2 emissions (IPCC, 1996). Besides CO_2 industry also emits various other GHGs, i.e. CFCs, HFCs, HCFCs, CH_4, N_2O, PFCs, CF_4, C_2F_6, and SF_6 IPCC, 1996). Between 1971 and 1990, industrial energy use grew at a rate of 2.1% per year, slightly less than the world energy demand growth of 2.5% per year. This growth rate of industrial energy use has slowed in recent years, falling to an annual average growth of 0.2% between 1990 and 1995, primarily because of declines in industrial output in the CEITs. Energy use in the industrial sector is dominated by the OECD countries, which account for 44% of world industrial energy use. Non-Annex I countries and CEITs used 37% and 20% of 1995 world industrial energy, respectively. Industrial production is growing at a fast rate in Non-Annex I countries. The trends in industrial energy use and CO_2 emissions are depicted in Table 9.1.

[Insert Table 9.1 here]

Industrial production is an important engine to increase the economic activity, generate employment, and build up the infrastructure in developing countries. Investment in industry seems to have a stronger relation with economic growth than investments in other sectors (UNIDO,1997). This can also be observed from the growing importance of industry in, and its contribution to the growth of a developing nation's economy (UNIDO,1997). High industrial growth also promotes technological change (UNIDO,1997). Capital investment in industry is important to achieve economic welfare in developing countries. Capital relates to physical (e.g. equipment), human (e.g. education) and technological capital (e.g. science, R&D). Industrialisation builds on the contribution of science and technology, as is evidenced by the Chinese economic development in the past decades (Song, 1997). However, industrial technology should fit the needs of the users in developing economies. Technologies developed for a specific industrial infrastructure (e.g. raw materials used (UNEP, 1997), relative shares of production costs) may not always be the right choice for another one, as is shown by examples of industrial technology applied in Tanzania (Yhdego, 1995) and India (Schumacher and Sathaye, 1998). Adaptation and development of technology to suit the needs is an essential step in the successful transfer of technology. Hence, technology transfer is a process, involving the trade and investment in technology, the selection (e.g. new, second-hand), adoption, adaptation, and dissemination of industrial technology, and, last but not least, capacity building, as science and technology are strongly related (Song, 1997) in the development of an industrial infrastructure.

Future growth of basic industries will, to a large extent, occur in developing countries. While developing countries are the most important markets for new and energy efficient processes, technology is still primarily developed in industrialised countries, despite the fact that the absolute demand for such technologies is stagnating or relatively low. Industrialised countries will be less favourable theatres for the innovation of technologies in the primary materials processing industries, if there are limited applications for such in industrialised countries. This development stresses the need both for technology adaptation to the prevailing conditions in developing countries, and intensified collaboration between suppliers and users of new industrial processes. Technology transfer needs to be studied within these perspectives. However, it seems that environmentally sound technologies do not transfer as rapidly as e.g. information technology, particularly with regard to developing countries. Also, the rapidly increasing role of transnational companies and foreign direct investment (UNCTAD, 1997) may change the patterns of technology transfer (see section 9.3). These issues warrant a specific study of transfer of environmentally sound industrial technology, with an emphasis on GHG abatement technologies.

In this chapter we describe the experiences with various forms of technology transfer. After a brief summary of the technologies for GHG mitigation, mainly based on previous IPCC reports, we discuss the trends in technology transfer from a 'macro' perspective (section 9.3). In section 9.3 we describe the trends from an economic perspective, and study magnitude and directions, as well as sources of investment and technology. In sections 9.4 and 9.5 we study the processes of technology transfer between and within countries, based on case-study material and other literature sources. Next, there is an evaluation of the analysed material and a description of the main lessons learned in section 9.6, and this is followedby a summary.

9.2 Climate Mitigation and Adaptation Technologies

Future reductions in CO_2 emissions are technologically feasible for the industrial sector of OECD countries if technologies comparable to the present generation of efficient industrial facilities are adopted during regular stock turnover (replacement) (IPCC, 1996?). For Annex I countries with economies in transition, GHG reducing options are intimately tied to the economic redevelopment choices and the form that industrial restructuring takes. In developing countries large potentials for adoption of energy and resource efficient technologies exist as the role of industry is expanding in the economy. Although the efficiency of industrial processes has increased greatly during the past decades, energy efficiency improvements remain the major opportunity (IPCC, 1996) for reducing CO_2 emissions. Efficient use of materials may also offer significant potential for reduction of GHG emissions (Gielen, 1998; Worrell *et al.*, 1997)(see Table 9.2). Much of the potential for improvement in technical energy efficiencies in industrial processes depends on how closely such processes have approached their thermodynamic limit. For industrial processes that require moderate temperatures and pressures, such as those in the pulp and paper industry, there exists long-term potential to maintain strong annual intensity reductions. For those processes that require very high temperatures or pressures, such as crude steel production, the opportunities for continued improvement are more limited using existing processes. Fundamentally new process schemes, resource efficiency, substitution of materials, changes in design and manufacture of products resulting in less material use and increased recycling can lead to substantial reduction in energy intensity. Furthermore, switching to less carbon-intensive industrial fuels, such as natural gas, can reduce GHG emissions in a cost-effective way (IPCC, 1996; Worrell *et al.*, 1997). In addition to stock replacement, which is an excellent opportunity to save energy, there are many low cost actions that can be adopted as part of good management practices. Table 9.2 provides categories and examples of technologies and practices to mitigate GHG emissions in the industrial sector (based on IPCC (1996)' WEC (1995), and Worrell *et al.* (1997)). This summary is by no means comprehensive, but rather an indication of the wide range of possibilities that exist within and among industrial sectors for reducing GHG emissions. For more specific technologies and information, the reader is referred to a wide body of literature, as has been described in the references mentioned above.

[Insert Table 9.2 here]

The sensitivity of industry to climate change is widely believed to be low, compared to that of natural ecosystems (IPCC, 1996). Climate change, however, may have (local and regional) impacts on availability of resources to industry as a result of changes in average temperature, precipitation patterns and weather disaster frequencies,; in particular, availability of water (as a resource, energy source or for cooling) and renewable inputs (industrial and food crops) may be affected . Industry thus also needs to adapt to climate change, depending on local conditions, e.g. by improving its water efficiency, by strengthening its flexibility to cope with fluctuations in input availability, by reducing the vulnerability of production for weather conditions, and through proper siting and adaptations of industrial facilities. This may include a wide variety of measures such as protecting industrial sewage cleaning installations from flooding by storm water, reducing dependence on water use for various purposes, and siting away from vulnerable coastal areas. Fluctuating water levels at sea or rivers may also affect the steady supply of resources to industrial facilities, as evidenced by the impact of extremely high water levels on river bulk transport on the Rhine river system. There are already examples in which water scarcity, has driven innovation into water efficient industrial technologies, which have significant energy efficiency improvements (and hence GHG mitigation potential) as spin off. For example, water scarcity was identified as a potential threat to the textile industry in Surat (India) in the early 1990s. This incited a local engineering firm to invest in the development of dyeing machines customised for local fabric quality. Water and energy consumption are only approximately 1/3 of the water and energy consumption of comparable dyeing machines available on the international market, while the investment is much lower due to local industry. Several hundreds of dyeing machines are now being installed annually in the Surat region, and efforts are underway to market the technology in other regions and abroad (Berkel *et al.*, 1996).

9.3 Magnitude of Current Technology Transfer

As countries develop from an agrarian society to an industrial urban economy the economic structure of a developing nation goes through a transition process, as described by Kuznets (1971). The structure of the economy is strongly dependent on the stage of development, and hence the technology needs. A World Bank study confirmed the transition patterns for a large number of economies (Syrquin and Chenery, 1988). The transition process may not be smooth (especially in short periods), and may follow various paths. Syrquin and Chenery (1988) showed that the performance of the economy is associated with large size, a manufacturing orientation and with a higher degree of openness. The smaller the economy, the more it relies on the open character of the economy. However, alternative paths may be successful too, as evidenced by the development of economies as in Korea, where industries matured under economic protection (Lee, 1997).

[Insert Figure 9.1 and Figure 9.2 here]

The rate of technological change strongly affects the rate of investment and the productivity and *vice versa*. Investment in modern equipment, evidenced by the economic growth in newly industrialised economies in East Asia, is seen as a more important contribution to growth than other investments (UNIDO, 1997). The growing industrial production in Asia, especially China (5% of world manufacturing value added (MVA) in 1995), is shown in Figure 9.1. Figure 9.1 also shows that world MVA is still dominated by the industrialised countries, while MVA of the economies in transition has decreased. The share of MVA from other regions of the world has remained stable. The regional development of the industrial sector is depicted in Figure 9.2. It shows that the importance of the industrial sector in the regional economy is increasing in most developing regions.

Although the growth pattern of the industrial sector may differ between countries, generally the growth is associated with the use of capital intensive technology such as in the raw material based industries. China, India (Kaplinsky, 1997) and Korea are examples of this pattern, though in different stages of development. , There is, however, considerable debate about the importance of the industrial sector in the economic development process. The growing importance of the services sector in some developing economies (Asia, Latin America) generates an increasingly larger part of total economic growth (World Bank, 1998). Different investment patterns influence industrial growth, structure and technology adoption.

We use investment flows as an indicator for investments and technology transfer. While, recognising that investment flows do not consider differences in the ‘quality’ of investments made, there is no other simple indicator for the magnitude of technology transfer taking place.

9.3.1 International Investment Patterns

Recent trends in industrial development stress the openness in trade and investments. Today, foreign direct investment (FDI), joint ventures (JV) by transnational corporations (TNC) are the largest foreign investments in industrial development in developing countries (UNCTAD, 1997) (see also Chapter 2). However, foreign capital accounts for only 6% (1995) of total investments in developing countries (UNIDO, 1997). In developing countries public spending is responsible for about a quarter of national income (World Bank, 1997a), while the role has relatively declined over the past 25 years (UNIDO, 1997).

[Insert Figure 9.3 and Figure 9.4 here]

Transnational corporations' spending in international investments increased from less than US$100 billion (B$) in the early 1970s to over US$1.4 trillion in 1996 (UNCTAD, 1997). The majority of the funds is still spent in industrialised countries, but an increasing part is spent in developing countries. Foreign industrial investment in developing countries has increased substantially, especially since 1990, as shown in Figure 9.3. Figure 9.3 shows that foreign industrial capital spending is concentrated in two regions, East Asia and Latin America. These regions have experienced successful industrial growth in the last decade, although concentrated in a small number of countries. Foreign direct investment, a part of the international investments, has grown to 350 B$ in 1996 (UNCTAD, 1997), of which 34% was invested in developing countries (see Figure 9.4).

Previous periods of high growth in FDI were mainly directed to oil producing countries. The current growth of FDI seems to be more diverse, although there is a strong geographic concentration in current FDI. Of the 129 B$ FDI in developing countries, 42 B$ was spent in China, followed by 10 B$ in Brazil (UNCTAD, 1997). Favoured regions are Asia and Latin America, and there are signs of increasing FDI in Africa, although still limited. Important is the increasing FDI from developing countries, especially Asia, which increased to 52 B$ (UNCTAD, 1997). In Asia regional investments seem to be the main driver for industrialisation. FDI in the former Central and Eastern Europe are relatively constant at 12-14 B$, but also concentrated in a few countries (Poland and the Czech Republic). Also, FDI is concentrated in a relatively small number of TNCs. Only a few (from Korea and Venezuela) of the top 100 TNCs are based in developing countries, yet TNCs from developing countries are growing in importance. TNCs seem to be most important in the electronics, automotive, and chemical industries, as well as petroleum and mining. TNCs seem to be more productive than domestic companies (UNIDO, 1997), which may be partly due to more efficient production technologies and practices used. The role of TNCs in industrial development is generally seen as positive, although negative effects may arise from TNC involvement if the market power of the TNC is high.

It appears that future trends in FDI will be sustained, as international trade seems to gain in importance, and as countries are liberalising trade and investment. FDI aims at accessing and developing markets, whereas portfolio equity investment (PEI) is more directed to participating in local enterprises. Following the globalisation trend PEI is also growing, but tends to be more centred on developed markets and to be more fluid. PEI is estimated at 45 B$ (1995) (UNCTAD, 1997).

Small and medium sized enterprises (SMEs) have less access to international financing, and hence rely more on domestic capital and public spending. Even small investments in cleaner production and GHG abatement projects in

SMEs are often not done, due to lack of capital, poorly developed banking systems, lack of appropriate financing mechanisms, lack of knowledge (both within the industrial and the financial sectors), technology risks, and management's unwillingness to borrow funds (Berkel and Bouma,1999). These barriers reduce the availability of capital, stimulating investors to keep investment costs low, which may result in the purchasing of second-hand equipment, low quality products, or equipment without modern controls and instrumentation. This may lead to higher operating costs, and environmental impacts. Lack of access to capital and credit is seen as the strongest barrier to the development of SMEs (UNIDO, 1997). Various developing countries have experimented and applied financing schemes for SMEs, e.g. Ecuador, Indonesia, Korea, Malaysia, Pakistan and Tanzania, with varying rates of success (UNIDO, 1997). Trends in foreign investments are relatively easy to monitor. However, domestic capital spending in developing countries/CEITs, especially by SMEs, is more difficult to monitor. Research in some developing countries shows that especially SMEs contribute for a large part to industrial employment, and that in LDCs industrial employment is found in rural areas (Little, 1987; Putterman, 1997; UNIDO, 1997). However, this does not necessarily mean that SMEs are more efficient with regard to capital and resource use (Little, 1987). There is growing evidence that SMEs in some countries may be less efficient with respect to resource use (World Bank, 1997b). Sound market conditions are crucial to create a competitive market in which innovation by SMEs in process technology is stimulated.

The above trends in industrial investments are difficult to translate to technology choice and transfer. It is obvious, though, that increasing international investments influences the rate of technology transfer, although it gives no information on the way and on what technology is transferred. Generally, the majority of investments in many developing countries seem to be in low-technology industries, though the share of high-technology industries is increasing (UNIDO, 1997). Also, there is no hard information available on the role of the markets for environmentally sustainable technologies (including greenhouse gas abatement) (Luken and Freij, 1995).

9.3.2 Official Development Assistance and Other Flows

Annual official development assistance (bilateral and multilateral) has averaged about 60 B$ since 1990 (UNIDO, 1990), of which only a small part is invested in industrial development. In the 1970s about 10% of foreign aid was invested in industrial infrastructure, but this decreased sharply during the 1980s and 1990s. Approximately 2% of bilateral and 6% of multilateral aid is spent on industrial development (UNIDO, 1997), or US$820 million (M$). Major recipients of development aid earmarked for industry are low to medium income countries, e.g. Bangladesh, China and Indonesia. In 1995 45% of the total budget was spent in these three countries (UNIDO, 1997). Official development assistance funds have been reduced in real terms in the past decade. Future trends in development aid are unclear.

Other financial flows include development loans and export credits, used primarily to finance the export of capital goods and equipment. In 1994 the lending of export credit agencies to developing countries and CEITs has increased to 420 B$ (UNIDO, 1997), but it is unclear what part is spent on industrial development and technology. Export credits and loans seem to be heavily concentrated in large low-income but creditworthy countries, and increasingly in countries that have (gained) access to international financial markets. However, the majority of low income developing countries have no access to these funds. Finally, the lending by multilateral financing banks to industry has decreased from 8.5 B$ in 1990 to about 4 B$ in 1994 (UNIDO, 1997). The reduction seems to be due to the reduced role of project lending by these banks, as well as the increased access of developing countries/CEITs to international capital markets (UNIDO, 1997).

9.3.3 Role of Research and Development

Scientific and technical capability are crucial to the economic and industrial development of developing countries (Rama Rao, 1997; Song, 1997; Suttmeier, 1997). Technology transfer is defined as the transfer and development of "hardware" and "software". The "software" may include scientific and engineering knowledge as well as managerial and operational skills. Direct investment in industrial R&D may be included in the investment figures discussed above. In industrialised countries the private sector is often the largest investor in R&D. However, in developing and transitional countries, the public sector is the largest contributor, e.g. in China (Song, 1997), the Czech Republic (Moldan, 1997) and India (Rama Rao, 1997; Tripathy, 1997). Although difficult to estimate, the R&D funds allocated to environmental technology are only a small part of the total industrial technology R&D budget. Energy R&D budgets of OECD countries have declined in past decades (Williams and Goldemberg, 1995). Less than 6% of the total energy R&D budget in IEA countries was spent on energy efficiency (incl. industrial technology), whereas most is allocated to nuclear technology R&D (IEA, 1994). Scientific knowledge and R&D are getting more and more internationally oriented, as evidenced by foreign direct investment in R&D. It is estimated that foreign corporation spending in the U.S. in 1994 amounted to 15 B$, or 15% of total industrial R&D spending (Florida, 1997). Generally, FDI in R&D is comparatively small, mostly directed to support local industry. However, FDI in R&D is growing rapidly, particularly in the U.S., and also the focus is changing to developing new products, obtaining information on local scientific developments and access to local human capital (Florida, 1997). International R&D collaboration can be an effective means of technology transfer (see, for example, Chapter 16, case study 4), and recent initiatives like the Climate Technology Initiative (CTI) can enhance this collaboration. Preliminary analysis seems to suggest that newly industrialised countries seem to increase the generation of scientific and technological knowledge within their countries, although the majority of knowledge is still generated in the industrialised world (Amsden and Mourshed, 1997). The type of scientific output and knowledge may vary by country. In India, in 1994 to 1995, total research expenditure is estimated to have been 0.8% of GDP (Rama Rao, 1997) and in China it was estimated at 0.5% in 1995 (Song, 1997), while total spending in science and technology development was estimated at 1.5% of GDP. The figures are slightly lower than the years before. However, no accurate information is available on the global role of and investments in scientific knowledge in developing countries.

9.4 Programmes and Policies for Technology Transfer within Countries

Technology transfer is a process involving assessment, agreement, implementation, evaluation and adaptation, and repetition. Although technology transfer is often seen as a private interaction between two companies or trade partners, institutional barriers and policies influence the transaction process, as well as the efficiency of the transfer process. In this section we will first discuss the barriers to technology transfer, followed by a discussion of existing programmes and policies within countries. A wide body of literature discusses the barriers and policies that affect implementation and diffusion of technologies (see e.g. Worrell *et al.*, 1997). We will concentrate on the experiences of programmes with respect to environmental and energy efficient technologies in developing countries and CEITs. Developing countries and CEITs suffer from all barriers that inhibit technology transfer plus a multitude of other problems. Potential conflicts in policies and goals between sectors can act as a barrier. For example, energy costs in industrialised countries often do not reflect the total costs, but the problem is especially serious in some developing countries and CEITs, where energy is considerably underpriced, with the government providing the energy supply industries (especially electric power producers) subsidies. Recently, subsidies in many countries have been reduced, possibly due to deregulation of the energy sector. Deregulation of the power sector may help to remove energy subsidies. Rigid hierarchical structure of organisations and the paucity of organisations occupying the few niches in a given area, lead to strong and closed networks of decision makers who are often strongly wedded to the benefits they receive from the status quo (see e.g. Gadgil and Sastry (1994) for an example of efficient lighting systems).

9.4.1 Barriers to Technology Transfer

Under perfect market conditions all additional needs for energy services are provided by the lowest cost measures, whether energy supply increases or energy demand decreases. There is considerable evidence that substantial energy efficiency investments that are lower in cost than marginal energy supply are not made in real markets, suggesting that market barriers exist. We first discuss barriers to the transfer of climate change technologies that apply to all economies, followed by a discussion of additional barriers that are of particular importance to developing nations.

Decision-making processes in companies are a function of their rules of procedure, business climate, corporate culture, managers' personalities and perception of the firm's energy efficiency (DeCanio, 1993; OTA, 1993). Energy awareness as a means to reduce production costs seems not to be a high priority in many companies, despite a number of excellent examples in industry worldwide (e.g. Nelson, 1994). Cost-effective energy efficiency measures are often not undertaken as a result of *lack of information* on the part of the consumer, or a lack of confidence in the information, or high transaction costs for obtaining reliable information (Reddy, 1991; OTA, 1993; Levine *et al.*, 1995; Sioshansi, 1991). Information collection and processing consumes time and resources, which is especially difficult for small companies (Gruber and Brand, 1991; Velthuijsen, 1995). Especially in many developing countries and CEITs, public capacity for information dissemination is lacking, which suggests the importance of training in these countries, and is seen as a major barrier for technology transfer (TERI, 1997). The problem of the information gap concerns not only consumers of end-use equipment but all aspects of the market (Reddy, 1991). Many producers of end-use equipment have little knowledge of ways to make their products energy efficient, and even less access to the technology for producing the improved products. End-use providers are often unacquainted with efficient technology. In addition to a lack of information at least two other factors may be important: a focus on market and production expansion, which may be more effective than efficiency improvements to generate profit maximisation; and the lack of adequate management tools, techniques and procedures to account for economic benefits of efficiency improvements.

Limited capital availability will lead to high hurdle rates for energy efficiency investments, because capital is used for competing investment priorities. Capital rationing is often used within companies as an allocation means for investments, leading to even higher hurdle rates, especially for small projects with rates of return from 35 to 60%, much higher than the cost of capital (~15%) (Ross, 1986). In many developing countries cost of capital for domestic enterprises is generally in the range of up to 30-40%. When energy prices do not reflect the real costs of energy (without subsidies or externalities) then consumers will necessarily underinvest in energy efficiency. Especially for SMEs, capital availability may be a major hurdle in investing in energy efficiency improvement technologies due to limited access to banking and financing mechanisms, as was also shown in the evaluation of a Japanese energy audit programme for SMEs (Oshima, 1998). Energy prices, and hence the profitability of an investment, are also subject to large fluctuations. The uncertainty about the energy price, especially in the short term, seems to be an important barrier (Velthuijsen, 1995). The uncertainties often lead to higher perceived risks, and therefore to more stringent investment criteria and a higher hurdle rate. Lack of skilled personnel, especially for small and medium sized enterprises (SME), leads to difficulties installing new energy-efficient equipment compared to the simplicity of buying energy (Reddy, 1991; Velthuijsen, 1995).

In many companies (especially with the current development toward *lean* companies) there is often a shortage of trained technical personnel, as most personnel are busy maintaining production (OTA, 1993). In CEITs the disintegration of the industrial conglomerates may lead to loss of expertise and hence similar implementation problems. In most developing countries there is hardly any knowledge infrastructure available that is easily accessible for SMEs. In Brazil, the SEBRAE programme provides institutional and technical assistance for SMEs, financed through a federal industry tax. SMEs are often a large part of the economy in developing countries. Special programmes may alleviate this barrier (see below).

In addition to the problems identified above, other important barriers include (1) the "invisibility" of energy efficiency measures and the difficulty of demonstrating and quantifying their impacts; (2) lack of inclusion of external costs of energy production and use in the price of energy; and (3) slow diffusion of innovative technology into markets (Levine *et al.*, 1994; Fisher and Rothkopf, 1989; Sanstad and Howarth, 1994). Regulation can, sometimes indirectly, be a barrier to implementation of low GHG emitting practices. A specific example is industrial cogeneration, which may be hindered by the lack of clear policies for buy-back of excess power, regulation for standby power, and wheeling of power to other users. Cogeneration in the Indian sugar industry was hindered by the lack of these regulations (WWF, 1996), while the existence of clear policies can be a driver for diffusion and expansion of industrial cogeneration, as is evidenced by the development of industrial cogeneration in the Netherlands (Blok, 1993). In addition, alternative models may be found important in focusing public policy on the need to raise end-user awareness and the priority to increase energy efficiency. This is likely to be an effective route to ensuring industry takes a comprehensive view of energy efficiency.

9.4.2 Programmes and Policies for Technology Transfer

In this section we will follow the steps in the transfer process, using experiences reported in the literature, as well as case studies (see Table 9.3). The steps we follow are: assessment, agreement, implementation, evaluation and adaptation, and repetition. Various programmes try to lower the barriers simultaneously in some steps. A wide array of policies to increase the implementation rate of new technologies has been used and tested in the industrial sector in industrialised countries (Worrell *et al.*, 1997), with varying success rates. We will not discuss general programmes and policies (e.g. taxation, subsidies, integrated resource planning, regulation and guidelines, voluntary programmes and information programmes; see Chapter 4), but rather concentrate on specific examples in the industrial sector, with an emphasis on developing countries' experiences. With respect to technology diffusion policies there is no single instrument to reduce barriers; instead, an integrated policy accounting for the characteristics of technologies, stakeholders and countries addressed is needed. Technology diffusion is also influenced by many parameters, including capital costs, resources, productivity and resource efficiency.

Assessment
Selection of technology is a crucial step in any technology transfer. Information programmes are designed to assist energy consumers in understanding and employing technologies and practices to use energy more efficiently. These programmes aim to increase consumers' awareness, acceptance, and use of particular technologies or utility energy

conservation programmes. Examples of information programmes include educational brochures, hotlines, videos, audits, and design-assistance, energy use feedback and labelling programmes. Information needs are strongly determined by the situation of the actor. Therefore, successful programmes should be tailored to meet these needs. Surveys in Germany (Gruber and Brand, 1991) and the Netherlands (Velthuijsen, 1995) showed that trade literature, personal information from equipment manufacturers and exchange between colleagues are important information sources. In the United Kingdom, the "Best Practice" programme aims to improve information on energy efficient technologies, by demonstration projects (demonstrating technologies in various industrial environments and conditions, information dissemination and benchmarking. The programme has been effective in achieving cost-effective energy savings, and is now replicated in various countries (Collingwood and Goult, 1998). In developing countries and CEITs technology information is more difficult to obtain. The case studies in India (TERI,1997; Berkel,1998a), see Table 9.3, show various efforts to organise technology users and to collect and distribute data. These efforts seem to be successful, and have even lead to the establishment of visions on technology development (TERI, 1997). In China, visions on technology needs have also been developed.

[Insert Box 9.1 here]

Energy audit programmes are a more targeted type of information transaction than simple advertising. Industrial customers that received audits reduced their electricity use by an average of 2 to 8%, with the higher savings rates achieved when utilities followed up their initial recommendations with strong marketing, repeated follow-up visits, and financial incentives to implement the recommended measures (Nadel, 1990; Nadel, 1991; Oshima, 1998). Energy audit programmes exist in numerous developing countries, and an evaluation of programmes in 11 different countries found that on average 56% of the recommended measures were implemented by audit recipients (Nadel *et al.*, 1991). The Indo-German energy audit project (see Box 9.1) in Indian industries (Menke, 1998) confirms that 50-60% of the recommendations were implemented, resulting in energy savings of 5-15%. Moreover, energy auditing proved to be a viable self-sustaining business opportunity, as the Indian partner was well equipped and motivated.

Agreement and Implementation

Actual implementation of technologies and practices depends on the motivation of management and personnel, external driving forces, e.g. legislation and standard setting, economics (i.e. profitability), availability of financial and human resources, and other external driving forces (e.g. voluntary agreements). Environmental *legislation* can be a driving force in the adoption of new technologies, as evidenced by the case studies for India (TERI, 1997) and the process for uptake of environmental technologies in the U.S. (Clark, 1997). Energy prices often do not reflect the full costs of energy production. Higher energy prices can increase the implementation rate of efficient practices, as evidenced by the Russian case study (Avdiushin *et al.*, 1997). Market deregulation can lead to higher energy prices in developing countries and CEITs (Worrell *et al.*, 1997), although efficiency gains may lead to lower prices for some consumers. Small energy or carbon taxes have been implemented for small energy users (incl. industry) in Denmark and the Netherlands, but it is too early to evaluate the effect on GHG emissions. Energy intensive industries operating in export-oriented markets are often exempted from such taxation schemes. The Czech case-study shows a scheme, somewhat similar to a "feebate", where funds from pollution fines are used to finance pollution prevention projects (Marousek *et al.*, 1998).

Direct subsidies and tax credits or other favourable tax treatments (to raise end-use energy efficiency) have been a traditional approach for promoting activities that are thought to be socially desirable. Incentive programmes need to be carefully justified to assure that social benefits exceed cost. Direct subsidies might also suffer from the "free rider" problem, where subsidies are used for investments that would be made anyway. Estimates of the share of "free riders" in Europe range from 50 to 80% (Farla and Blok, 1995), although evaluation is often difficult. An example of a financial incentive programme that has had a very large impact on energy efficiency is the energy conservation loan programme that China instituted in 1980.

This loan programme is the largest energy efficiency investment programme ever undertaken by any developing country, and currently commits 7% to 8% of total energy investment to efficiency, primarily in heavy industry. The programme not only funded projects that on average had a cost of conserved energy well below the cost of new supply, it also stimulated widespread adoption of efficient technologies beyond the relatively small pool of project fund recipients (Levine and Liu, 1990; Liu *et al.*, 1994). The programme contributed to the remarkable decline in the energy intensity of China's economy. Since 1980 energy consumption has grown at an average rate of 4.8% per year (compared to 7.5% in the 1970s) while GDP has grown twice as fast (9.5% per year), mainly due to falling industrial sector energy intensity. Of the apparent intensity drop in industry in the 1980s, about 10% can be attributed directly to the efficiency investment programme (Sinton and Levine, 1994), and a larger amount from unsubsidised efficiency investments, efficiency improvements incidental to other investments, and housekeeping measures. Economic reforms in many countries opened China's economy, which has favoured growth of light industries over heavy industries. The industrial structure has thus changed remarkably, in favour of less energy intensive sectors (World Bank, 1997b).

New approaches to industrial energy efficiency improvement in industrialised countries include voluntary agreements (VA). A VA generally is a contract between the government (or another regulating agency) and a private company, association of companies, or other institution. The content of the agreement may vary. The private partners may promise to attain a certain degree of energy efficiency improvement, emission reduction target, or at least try to do so. The government partner may promise to financially support this endeavour, or promise to refrain from other regulating activities. Various countries have adopted VAs directed at energy efficiency improvement (IEA, 1997a). No thorough evaluations of VA schemes have been published yet. Experiences with early environmental VAs varied strongly - from successful actions to very limited impacts (Worrell *et al.*, 1997). In some cases the result of a voluntary agreement may come close to those of regulation. Voluntary agreements can have some apparent advantages above regulation, in that they may be easier and faster to implement, and may lead to more cost-effective solutions. Some NICs, e.g. Korea, also consider the use of VAs (Kim, 1998), while the Global Semiconductor Partnership is an example of an international voluntary agreement by TNCs to reduce PFC emissions, to avoid regulation (Andersen, 1998a).

Evaluation and Adaptation

Every industrial facility is unique in the process equipment used, lay-out, resources used, and organisation. Translation from a generic technology level into practical solutions within a country, sector or individual plant is needed. In UNIDO's National Cleaner Production Programme, it was found that investors only accepted the results of a technology demonstration if these are generated in a situation similar to theirs (Berkel, 1998b). Among other activities, the "Best Practice" programme in the UK (and replicated in China (Dadi *et al.*, 1997), Brazil, Australia and New Zealand) demonstrates a technology in different industrial applications. Various countries have subsidy programmes under which new applications of technologies are eligible. Unless the capacity to adapt technology to the specific circumstances is developed, either in industry or technical assistance providers, investments in clean and energy efficient technology will not be successful.

Repetition

Research and development can have various goals, depending on the barriers to be tackled to implement a technology. Blok *et al.* (1995) differentiate between technical development of a technology, improving the technology to reduce costs, and exploration and alleviation of barriers to the implementation of a technology. The challenge of climate change is to achieve substantial GHG emission reductions over time, which can only be reached by building (technological) capacity through sustained RD&D efforts. Large potential efficiency improvements do exist in the long term (Blok *et al.*, 1995). A recent US study (DOE, 1995) quotes many successes of energy RD&D. There is consensus among economists that R&D has a payback that is higher than many other investments, and the success of R&D has been shown in fields like civilian aerospace, agriculture and electronics (Nelson, 1982). Still the private sector has a propensity to under invest in RD&D, because it cannot appropriate the full benefits of RD&D investments, due to "free riders" (Cohen and Noll, 1994). Companies will also under invest in RD&D that reduces costs not reflected in market prices (Williams and Goldemberg, 1995), such as air pollution damages and climate change. The example of the Waste Minimisation Cycles in India (Berkel, 1998a) demonstrates further development of technologies to improve performance, through a network of industries from the same industry sector to reduce some of the barriers. The Brazilian Alcohol programme is an example of indigenous technology development. Although seen as expensive due to lower oil prices since 1986 (Oliveira, 1991; Weiss, 1990), it is seen as a success in the field of technology development. Development has decreased the production costs of alcohol considerably (Goldemberg and Macedo, 1994; Macedo, 1998). Copersucar, a cooperative of sugar and alcohol producers, operates a (leading) joint research centre for agricultural and technology development (Macedo, 1998), as well as training. The centre also maintains a benchmarking programme to monitor and improve performance among members.

[Insert Table 9.3 and Table 9.4 here]

9.5 Programmes and Policies for Technology Transfer between Countries

As in the previous section, here we will follow the steps in the transfer process, using experiences reported in the literature, as well as case studies (see Table 9.4). We focus on the transfer of technology between countries. The steps we follow are; assessment, agreement, implementation, evaluation and adaptation, and repetition. In this regard we give strong emphasis to the adaptation, assimilation and repetition of technologies in developing countries and CEITs.

9.5.1 Barriers to Technology Transfer between Countries

Developing countries and CEITs suffer from the same factors that inhibit transfer of environmentally sound technologies as in industrialised countries (see section 9.4.1), plus a multitude of other problems. The problems also hinder transfer between countries.

High inflation rates in developing countries/CEITs and lack of sufficient infrastructure increase the risks for domestic and foreign investors and limit the availability of capital. Lack of capital may result in the purchasing of used industrial equipment (Sturm *et al.*, 1997), resulting in higher energy use and/or GHG emissions, as well as higher production costs. Trade in second- hand industrial equipment to developing countries and CEITs is quite common in most industrial sectors, e.g. cement, chemical, pulp & paper and steel industries. National trade and investment policies may limit the inflow of foreign capital. This might be a barrier to technology transfer (see also section 9.3). Recent liberalisation of investment regimes, in e.g. the mining industry, is seen as a way to transfer and acquire new technologies and reduce environmental damage (Warhurst and Bridge, 1997). This also applies to the role of TNCs and their role in technology transfer (see e.g. Chapter 16, case study 13). The technology cooperation to phase out the use of PFCs in the manufacture of semiconductors in the Global Semiconductor Partnership provides an example of cooperation between TNCs as a way to improve access of knowledge and technologies (Andersen, 1998a) within a more liberalised market, and a way to avoid command and control regulations.

Information about and assessment of technologies provided by foreign suppliers is more difficult for local investors in developing economies. Dependence on foreign suppliers may also induce risks in the case of technological support. For almost all industries the major suppliers can be found in the industrialised world, although some developing countries (e.g. China, India) or sectors (e.g. sugar cane processing) develop and supply indigenous and even advanced technologies (e.g. Korea) as well. Experience has shown that environmental considerations should be more carefully integrated into development and corporation policies. The policies in technology producing countries for transfer of environmentally sound technologies to developing countries seem to be inadequate (UN, 1998). In developing countries and CEITs a lack of protection of intellectual property rights may exist, which is seen as a barrier by technology suppliers (UN, 1998). Also, technology licensing procedures may be time consuming, leading to high transaction costs. Besides the problems with technology selection and supply, inadequate environmental policies, or implementation thereof, in developing countries and CEITs may reduce the demand for such technologies.

Basically, similar problems affect the international transfer of technology, but even more severely. This illuminates the need for closer collaboration between industrialised and developing countries as well as CEITs, especially in the areas of technological innovation, strengthening of local capacity, and increased training and information. In the next section we will discuss international experiences with technology transfer, based on case studies and available literature.

9.5.2 Programmes and Policies for Technology Transfer between Countries

Energy efficiency and GHG emission abatement could be viewed as an integral component of national and international development policies. Energy efficiency is commonly much less expensive to incorporate in the design process in new projects than as an afterthought or a retrofit. In the environmental domain, we have learned that "end of pipe" technologies for pollutant clean-up are often significantly more expensive than project redesign for pollution prevention, leading to widespread use of pre-project environmental impact statements to address these issues in the planning phase. Energy efficiency should also be incorporated into the planning and design processes wherever there are direct or indirect impacts on energy use such as in the design of industrial facilities, reducing the costs for energy supply and reducing the risks of local air pollution. This has not always been the case, as shown by Callin *et al.* (1991) for the investment in a new paper mill in Tanzania. Local circumstances often limit even the small investments needed for cleaner production and GHG abatement, due to lack of capital, poorly developed banking systems, lack of appropriate financing mechanisms, lack of knowledge (both within the industrial and financial sectors), technology risks, and management’s unwillingness to borrow funds (Berkel and Bouma, 1998). These barriers reduce the availability of capital, stimulating investors to keep investment costs low, which may result in selection and purchase of inappropriate technologies.

Most policies and programmes for the transfer of environmentally sound and greenhouse gas abatement technologies are national, and only a few are internationally oriented. Examples of the latter are the Greenhouse Gas Technology Information Exchange (GREENTIE) of the OECD/IEA, the PHARE programme of the European Union with Central and Eastern-Europe, and various bilateral programmes, e.g. US-AEP (U.S. and various Asian countries), Green Initiative (Japan), and the Technology Partnership Initiative of the UK. Most industrialised (donor) countries have policies in place, but strongly connected to (technology) interests of the donor country. Joint Implementation or Activities Implemented Jointly (JI/AIJ) may also be a useful energy efficiency promotion instrument. JI (see also Chapter 3) involves a bi- or multi-lateral agreement, in which (donor) countries with high greenhouse gas abatement costs in implementing mitigation measures in a (host) country with lower costs receive credit for (part of) the resulting reduction in emissions. Under COP3 the Clean Development Mechanism (CDM) (see also Chapter 3) has been introduced as a means to accelerate emissions reduction and credit emission reductions from project activities in Non-Annex I countries to Annex I countries. The criteria for JI/CDM are still in the process of development (Goldemberg, 1998). Most likely the projects should fit in the scope of sustainable development of the host country (without reducing national autonomy and with cooperation of the national government), have multiple (environmental) benefits, be selected using strict criteria and be limited to a part of the abatement obligations of a donor country (Jepma, 1995; Pearce, 1995; Jackson, 1995). Determination (and crediting) of the net emission reductions is a problem that stresses the need of well-developed baseline emissions (La Rovere,1998), i.e. emissions that would occur in the absence of the project (Jackson, 1995). JI/CDM can prove to be a viable financing instrument to accelerate developments in CEITs and in developing countries, if implemented according to specific criteria (Goldemberg, 1998). Comprehensive evaluation of pilot projects is necessary to formulate and adapt these criteria, including the issue of crediting.

Assessment

Technology assessment and selection is very important. However, often the capacity is missing, or the selected technology is determined by a donor country or by available financing (e.g. bilateral export loans or tight aid). This may lead to sub-optimal technology choices (Schumacher and Sathaye, 1998, Yhdego, 1995). An important arena for cooperation between the industrialised and developing countries therefore involves the development and strengthening of local technical and policy-making capacity, for example, for an assessment of (technical) needs. Large companies may be able to access information or resources or hire engineering companies more easily, like in the chemical industry (Hassan, 1997). SMEs and local companies have generally less easy access to external resources. Project-oriented agencies eager to show results commonly pay inadequate attention to the development of institutional capacity and technical and managerial skills needed to make and implement energy efficiency policy.

The Japanese Green Assistance Plan aims at supporting Japanese exports of energy efficient technologies to other Asian countries, including China and Thailand (Sasaki and Asuka-Zhang, 1997). It is not always clear how the technologies supported under this programme are selected. Hu *et al.* (1998) made a report on the transfer of dry coke quenching technology from Japan to China, as part of the Japanese Green Assistance programme and JI/AIJ. The payback period under current Chinese conditions is 7 years (Hu *et al.*, 1998). The recipient, Capital Steel, had no choice in the technology selection, as the transfer was the product of cooperation between both governments. Projects in India (Menke,1998; Berkel, 1998b), as well as Leadership Programmes under the Montreal Treaty in Thailand and Vietnam aimed at the development of the needed capacity (Andersen, 1998b). The Indian projects proved to be successful, in the sense that they built active capacity assessing needs and opportunities for energy efficiency improvement and clean technologies for industries in various regions (see also Box 9.2). Formal recognition of the acquired skills in knowledge transfer seems to be important to improve the status of a program (Berkel, 1998a). International partnerships of firms can be a successful tool to transfer technologies, as shown in the Vietnam Leadership Programme between various TNCs active in Vietnam and government agencies to phase out the use of CFCs in the Vietnamese electronics industry (Andersen, 1998b). The example of bilateral cooperation between U.S. electronics manufacturers and Mexican suppliers helped to overcome some of the barriers in information supply and access to technology and financing (Andersen, 1998c).

[Insert Box 9.2 here]

As industrial development increases, capabilities for technology assessment and selection improve, as evidenced by the case study of pulverised coal injection for blast furnaces in the steel industry in Korea (Joo, 1998c), as well as by investment projects in new cement plants in Mexico (Turley, 1995) and Chinese Taipei (Chang, 1994). It is stressed that development of technical capabilities is a continuous process, because it takes large resources to build up a knowledge infrastructure, and the key to success is so-called "tacit knowledge" (unwritten knowledge obtained by experience) (Dosi, 1988), which is easily lost. The greater the existing capability, the greater the opportunities are for gaining knowledge from industrial collaboration and technology transfer (Chantamonklasri, 1990). Finally, language can be a barrier in successful transfer of a technology, especially when working with local contractors or suppliers (Hassan, 1997).

Agreement and Implementation
As in adoption of technology and practices within countries, adoption across countries depends on the motivation of management and personnel, external driving forces, e.g. legislation and standard setting, economics (i.e. profitability), availability of financial and human resources, and other external driving forces (e.g. voluntary agreements). Financing in particular may be more difficult, hindered by high inflation rates, and needing hard currencies to acquire technologies. Budgets of multilateral financing institutes are relatively small, while bilateral financial assistance schemes may influence the technology selection (see above). The example of the Montreal Protocol Multilateral Fund shows that efficient and effective financing mechanisms can be deployed, although specific barriers may delay the financing schemes, as happened in Mexico (Andersen, 1998c). The case studies have shown that financing schemes for small companies, e.g. soft-loans, subsidies and tax credits, may help to improve the adoption rate (TERI, 1997). Large companies in NICs seem to have easier access to capital, as shown by the case studies for the steel industry in Korea (Joo, 1998a,b and c). Trade barriers, such as import taxes, can influence the economic assessment, and hence technology selection and implementation.

Evaluation and Adaptation
Adaptation of technologies to local conditions is crucial. There is a great need for technological innovation for energy efficiency in the developing countries and CEITs. The technical operating environment in these countries is often different from that of industrialised countries. For example, different raw material qualities, lower labour costs, poorer power quality, higher environmental dust loads, and higher temperatures and humidities require different energy efficiency solutions than successful solutions in industrialised country conditions. Technologies that have matured and been perfected for the scale of production, market, and conditions in the industrialised countries may not be the best choice for the smaller scale of production, raw materials used or different operating environments often encountered in a developing country. Transferred technologies seldom reach the designed operational efficiencies, and often deteriorate over their productive life (TERI, 1997) due to several reasons. Improper maintenance, inadequate availability of spare parts and incomplete transfer of "software" are some of the problems. This stresses the need for effective adaptation strategies, including transfer of technical and managerial skills (see also Box 9.3). Technical training is a very important aspect of a technology transfer (Hassan, 1997), and should preferably be done in the local language.

[Insert Box 9.3 here]

In practice, adaptation practices vary widely in various countries. For example, Chinese enterprises have spent, on average, only 9 (US) cents on assimilation for every (US) dollar on foreign technology. In contrast to countries as Korea and Japan where the amounts spent on assimilation were greater than those spent on technology itself (Suttmeier, 1997). Countries in a later stage of industrialisation may be better equipped for adapting technologies to the local industrial environment, while countries or companies in an earlier stage may (have to) rely more on the foreign suppliers of technology. Equipment suppliers may license part of the construction or parts supply to local firms. This is illustrated by the construction of an advanced steel plant in Korea, which was partly done by Samsung Heavy Industries (Worrell, 1998), as well as examples in the construction of cement plants in India (Somani and Kothari, 1997), Mexico (Turley, 1995) and Chinese Taipei (Chang, 1994). The examples in Korea, Mexico and Chinese Taipei show a heavy involvement in technology procurement, design and management. The Korean and Mexican firms belong to the largest producers in the world of respectively steel and cement.

Repetition
Replication and further development of practices and technologies in developing countries and CEITs is needed. It is also a heavily debated issue involving intellectual property rights (see Chapter 3), and dependence on (foreign) technology suppliers. Many industrial technologies are privately owned, although (part of) the (pre-competitive) research may have been publicly funded. When transferring dry coke quenching technology to China the proprietary rights stayed with the Japanese technology providers for a period of 10 years, avoiding replication in China for a long period (Hu *et al.*, 1998). A clear (legal) framework is needed to improve adaptation and replication of technology (ESETT, 1991). Technology transfer projects need continued support from the technology supplier. This is beneficial to both the technology user and supplier. The user can benefit from experience from other licensees, and the licensor gets an opportunity to gain further market entrance. Experience has shown that reasonable plant performance will

improve future business opportunities (Hassan, 1997). However, technology owners may be hesitant to share all parts of a technology, including "software", without sufficient legal protection in the country of the user (see Chapter 3).

Various concepts of replication and development are demonstrated by other case studies. Waste Minimisation Circles were started in a few regions in India, and are now replicated in other sectors and regions (Berkel, 1998a). UNIDO/UNEP replicated National Cleaner Production Centres in various developing countries and CEITs (Berkel, 1998b). Replication of programmes and experiences as a form of South-South cooperation is demonstrated by the transfer of the Indian auditing programme to Jordan (Menke, 1998). The examples of furnace technology development for SMEs in India through joint organisations (e.g. research institutes, NGOs) demonstrate the benefits of combining the experiences and strengths of various partners in innovative development and implementation schemes (TERI, 1997). Countries possessing a higher technical capability are faster to replicate and develop a technology. The first implementation of pulverised coal injection in a blast furnace in Korea made it possible to replicate the technology in another plant (Joo, 1998c) of the same company. The examples of the FINEX (fine-ore-based smelt reduction) process development, as well as the development of the HYL direct reduction process in Mexico (Zervas *et al.*, 1996), illustrate the capability of companies in NICs to develop a new process. The advanced FINEX project is an example of technology cooperation between the Austrian supplier and the Korean industry (Joo, 1998b). The steel sector is an industry with relatively frequent and open communication. In other sectors, e.g. the chemicals industry, process and technology knowledge is proprietary, limiting replication and development for developing countries and CEITs. Licensors and contractors are interested in the successful transfer of proprietary technology to secure future sales (Hassan, 1997).

9.6 Conclusions

The industrial sector is extremely diverse and involves a wide range of activities including the extraction of natural resources, conversion into raw materials, and manufacture of finished products. Due to the wide variety in activities, energy demand and GHG emissions vary widely. Hence, the aggregate energy use and emissions depend on the structure (or specific set of activities) of industry, and the energy and carbon intensity of each of the activities. The structure of industry may depend on the phase of the economy, as well as many other factors like resource availability and historical factors. Industrial production and GHG emissions are still dominated by industrialised countries, but the role of developing countries in world industrial production, especially South-East Asia, is increasing. Cost-effective potentials and opportunities for GHG emission abatement exist in all regions and industrial sectors. A wide variety of practices and technologies to reduce GHG emissions are available (see Table 9.2), often with high paybacks.

In industry, energy efficiency is often the result of investments in modern equipment, stressing the attention to sound and environmentally benign investment policies. Investments in technology (including hardware and software) in the industrial sector are dominated by the private sector. Recent trends in globalisation of industry seem to affect the international transfer of investments and technology. Foreign direct investment (FDI) is rapidly increasing, although concentrated on a small number of rapidly industrialising countries. These countries may have an impact on regional industrial development patterns, as seen in Asia. Private investment in other developing regions is still limited, although increasing. FDI is dominated by transnational companies, while SMEs in industrialised, developing countries and CEITs have less access to (international) financial markets and technologies. Although difficult to measure, domestic investments in developing countries are still larger than FDI. Official development assistance, although earmarked for low to medium income countries, is also concentrated on a few countries. Public funding (in industrialised, developing countries and CEITs) for technology development and transfer, although still important, is decreasing. Funding for science and technology development is important to support industrial development, especially in developing countries. Public funding in the industrial sector, although small in comparison to private funding, remains important but its future role may be changing. Regular evaluation of the goals of public funding is needed for industrial development with respect to the role of cleaner technologies and with respect to the role of private funds.

Barriers limit the uptake of more efficient technologies. These barriers may include the (un)willingness to invest in (new) technologies, the level of information and transaction costs, the lack of effective financing (e.g. lack of sufficient funds, high interest), the lack of skilled personnel and a variety of other barriers, e.g. the "invisibility" of energy and CO_2 emission savings and the lack of inclusion of external costs. Developing countries and CEITs suffer from all of these factors that inhibit market acceptance of technologies plus a multitude of other market problems. Consumers often have no knowledge of energy efficiency (technologies) or cannot afford increases in equipment costs, due to a limited ability to pay increased initial costs, limited foreign currency and high inflation rates. A well developed banking system and existence of appropriate financing mechanisms are essential for the uptake of efficient and cleaner technologies in industry.

Traditionally, technology transfer is seen as a private transaction between two enterprises. However, innovation and technology transfer is an interactive and iterative process, involving many different parties. An effective process for technology transfer will require interactivity between various users, producers and adaptors of technology. The variety of stakeholders makes it necessary to have a clear policy framework as part of an industrial policy for technology transfer and cooperation, both for a technology donor and recipient or user. Such a framework may include environmental, energy, (international) trade, taxation and patent legislation, as well as a variety of well-aimed incentives. The framework may help to give the right signals to all parties, as well as help to develop innovative concepts for technology assessment, financing, procurement, adaptation, repetition and development. Policymakers are responsible for developing such a comprehensive framework. The interactive and dynamic character of technology transfer stresses the need for innovative and flexible approaches, through (long-term) partnerships between various stakeholders, including public-private partnerships.

The case studies and the literature demonstrate clearly that there is a strong need to develop the capacity to assess and select technologies. Stakeholders (policymakers, private investors, financing institutions) in developing countries and CEITs have even more difficult access to technology information, stressing the need for a clearinghouse for information on climate abatement technology. Various innovative policy concepts, including networking and joint research and information organisations, were found to be successful. To increase the likelihood of success, long term support for capacity building is essential, stressing the need for public support for capacity building and cooperation of technology suppliers and users.

Adaptation of technology to local conditions is essential, but practices vary widely. Countries that spend on average more on adaptation seem to be more successful in technology transfer. As countries industrialise the technological capabilities increase rapidly, accelerating the speed of technology diffusion and development. This demonstrates that successful technology transfer includes transfer of technological capabilities, which may be beneficial to both the supplier and user. Technology users, suppliers as well as financial institutions and governments could give attention to adaptation as an essential and integral part of technology procurement.

The introduction and diffusion of clean or low-GHG technologies in the industrial sector needs a sound environmental and economic policy, stressing the need for long term goals and commitment by policymakers. This also means that technology transfer needs to be incorporated in R&D strategies, as many (public) environmental sound technologies “remain on the shelves” and are not brought into the market as rapidly as may be expected. Several countries and equipment suppliers envisage that environmentally sound product development can enhance the future competitive position of domestic suppliers, making technology transfer (through strengthening local capacity and demonstration of technology) a way to open new export markets. Subsequently, policies to support the development of new technologies and markets could be used in these countries as part of economic and trade policies.

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Box 9.1.

Information and methods to identify and assess opportunities for greenhouse gas emission abatement and energy efficiency are essential steps in the successful implementation of these practices and technologies. Energy audits for industries have been used as a tool to bridge this information gap. In India, energy audits for industry had a bad history, as historically these were often subsidised and provided at almost no cost. Often the quality of the audits was very low. Consequently, recommendations were seldom implemented by the recipient. The cooperation between Tata Energy Research Institute (TERI, New Delhi), India, and the German organisation for Technical Cooperation (GTZ) aims to strengthen the capabilities of the TERI Bangalore Centre, to provide energy audits for industry and to strengthen the capabilities to offer high quality advise to industry. The Indo-German project provided various forms of training, established an energy information centre, provided improved measuring instruments for energy audits, helped to re-organise the institution by building specialized teams for the various industrial sectors, and helped to establish South-South cooperation. The energy audit centre in Bangalore has established itself, now has nine years of experience in providing energy audits to industry in India, and has expanded from having eight to more than 25 energy experts. This has provided the critical mass for the success of the project. It is planned to replicate this process in other parts of India and other countries. Currently the Jordan-German Rational Use of Energy Project is an attempt to replicate the positive experiences from India, by twinning the Jordan Institute with TERI (Menke, 1998).

Box 9.2.

The basis of successful technology transfer is the capacity to adapt, operate and integrate a new technology. The National Cleaner Production Centre (NCPC) Programme is a global project managed by UNIDO, together with UNEP. The Programme aims to facilitate the application of cleaner production in industry and the incorporation of the concept in policies of developing countries and economies in transition. In collaboration with a host institution, the programme establishes a unit (called NCPC) that provides continuous support to cleaner production initiatives in companies, business organisations, and local and national governments. An NCPC undertakes four sets of activities: in-plant demonstrations, training, information dissemination and policy advice. These activities can differ in intensity and form, depending on the situation in a country. The programme has established NCPCs in Brazil, China, Costa Rica, India, Czech and Slovak Republics, El Salvador, Guatemala, Honduras, Hungary, Mexico, Nicaragua, Tanzania, Tunisia, and Zimbabwe. New centres are being established in Slovenia, Croatia, Vietnam, and Morocco. Experiences with the NCPCs have showed that disseminating knowledge on cleaner production and showing the gains were not sufficient to spur the demand in industry. The programme will need to improve the identification of the needs of companies and responding to these needs. There is a need to formalise the process, e.g. by linking cleaner production concepts to certification systems like ISO 14000. Replication needs several prerequisites to be successful including: effective environmental policy, regulation and enforcement, environmentally sound behaviour (embedded in society); the use of operational, accounting and management systems for data collection in industries; and a relation between cost of inputs, waste and emissions and the proceeds of the output. Access to adequate financing is also necessary to enable industry to invest (Berkel, 1998b).

Box 9.3

Much of China's coal consumption is in inefficient polluting equipment. Coal burning is a major contributor to air pollution in many Chinese cities. The average boiler efficiency of small and medium capacity industrial boilers, which consume approximately 1/3 of China's annual coal production, is only 60 to 65% (LHV, Lower Heating Value). In China there are already about 2000 fluidised bed boilers burning low grade coal. However, almost all of them are bubbling fluidised bed combustion (BFBC) boilers that have performance disadvantages and development limitations. In OECD countries, a new generation of circulating fluidised bed combustion (CFBC) concept has been developed. CFBC addresses the problems of combustion efficiency and air pollutant emissions. It was decided to demonstrate imported CFBC technology to China's coal users. Ahlstrom Pyropower was selected as the technology supplier. The project aimed to demonstrate CFBC technology at an existing industrial site, and enhance the capacity of China to design, manufacture, install and operate CFBC systems in various sizes with the flexibility to burn numerous coal types. The planned project costs of US$8.5 million (M$) were exceeded by 2 M$. UN funds provided 2 M$ and the Chinese Government provided 8.5 M$. Government input in kind was estimated at RMB 292 million (35.3 M$[2]) to meet other costs in China. The cost overrun was due to additional auxiliary equipment that needed to be imported. Eight training groups consisting of 16 researchers and engineers were trained in OECD countries, while over 174 Chinese engineers participated in a training workshop held in China. The R&D facilities provide a necessary tool for CFBC technology development in China. At least seven domestic boilermakers are now involved in CFBC design and construction, with a total of over 200 units either in operation, construction or under contract (Williams, 1998).

[2] This figure is based on a currency exchange rate from November 1999.

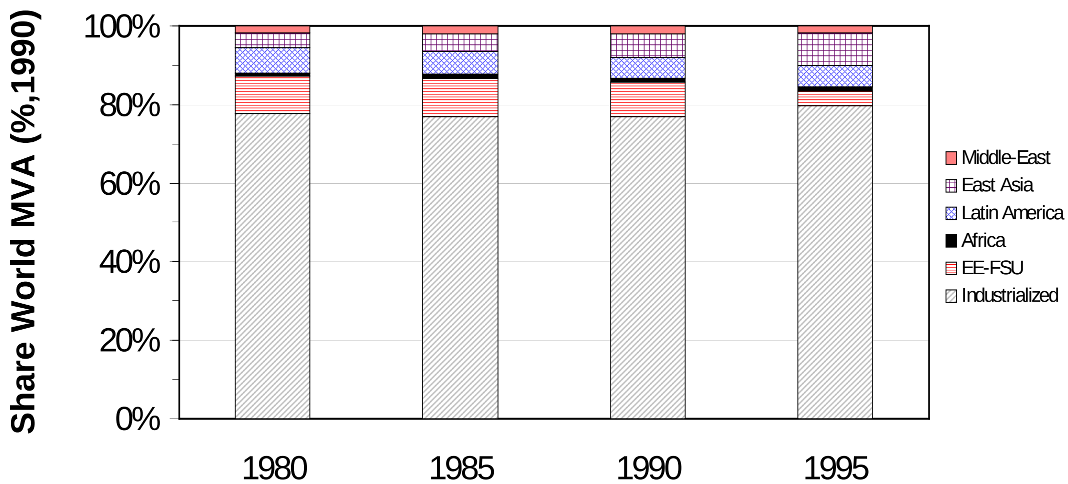

Figure 9.1. Regional shares of world manufacturing value added (MVA). Source: International Yearbook of Industrial Statistics 1997, UNIDO.

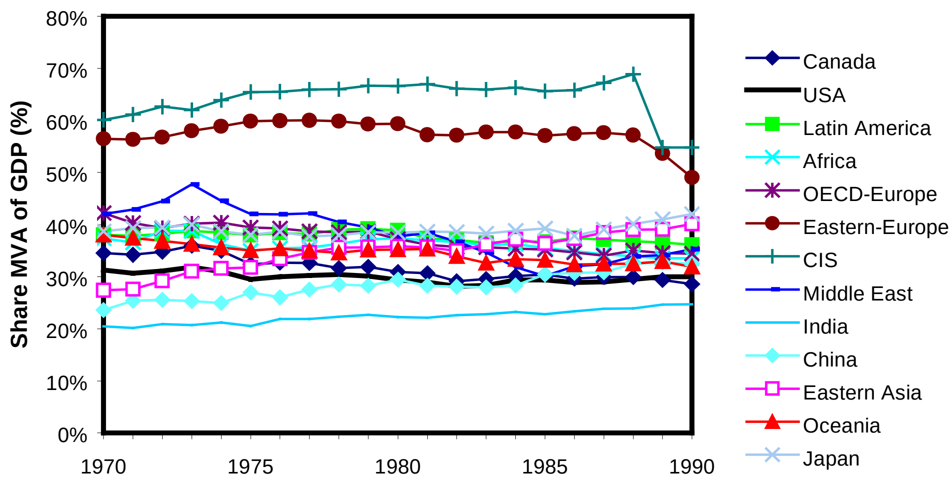

Figure 9.2. Development of manufacturing value added (MVA) as function of GDP in various regions. Source: IMAGE data supplied by RIVM, The Netherlands, 1998.

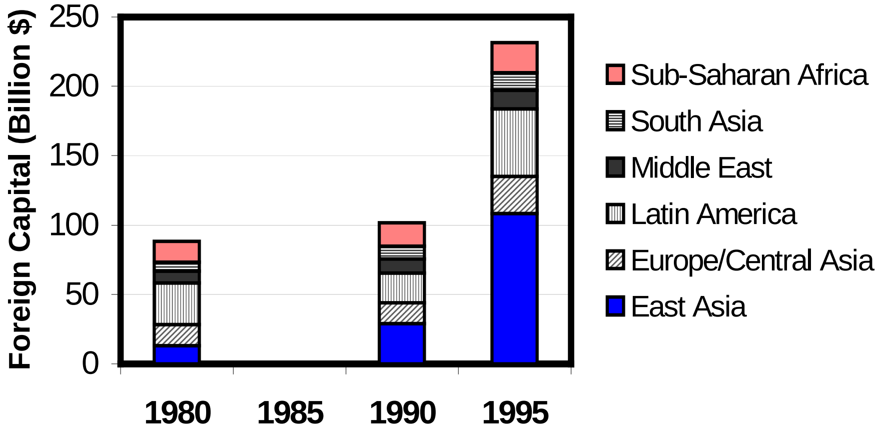

Figure 9.3. Foreign capital investment (Billion US$) in developing countries, by region. Source: Industrial Development, Global report 1997, UNIDO.

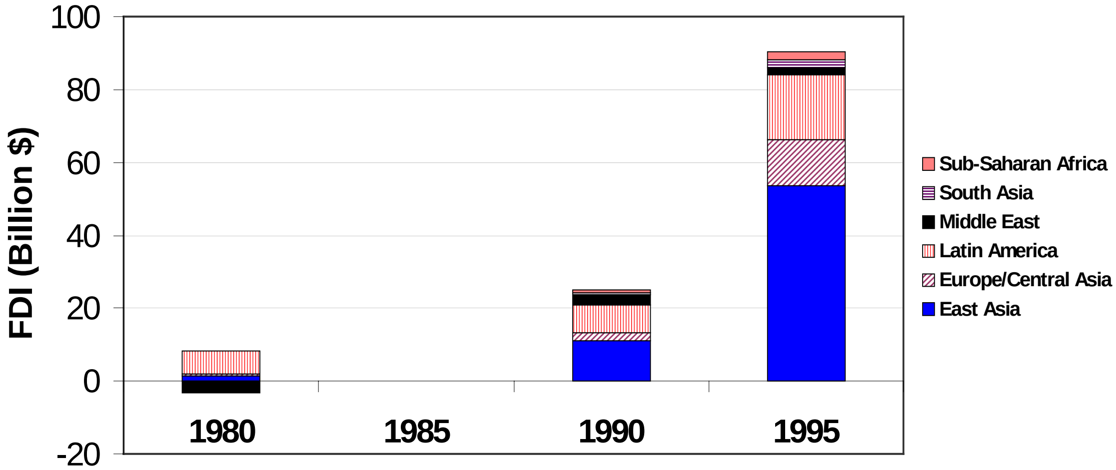

Figure 9.4. Foreign direct investment (Billion US$) in developing countries, by region. Source: Industrial Development, Global report 1997, UNIDO.

Table 9.1. Historical Energy Use in Industry (EJ). Primary energy consumption is calculated using a 33% conversion efficiency for electricity generation for all years and regions. Source: Price et al. (1998).

Region	Total Industrial Energy Use (EJ)					Average Annual Growth rate (%/annum)		
	1960	1971	1980	1990	1995	1960-1990	1971-1990	1990-1995
OECD	28	49	55	54	57	2.3	0.6	0.9
EE-FSU		26	34	38	26		2.0	-7.3
Developing Countries		13	24	37	48		5.4	5.0
World		88	114	129	131		2.1	0.2

Table 9.2 Categories and selected examples of practices and technologies to mitigate GHG emissions in the industrial sector, based on SAR II, WEC (1995), Worrell et al. (1997).

Option	Measures	Climate and Other Environmental Effects	Economic and Social Effects	Administrative, Institutional and Political Considerations
End Use				
Energy Efficiency Gains -more efficient end uses -reduction of energy losses	-Market Mechanisms -Voluntary Agreements -Energy Price Reform -Information programmes -International Corporation	-Savings on CO_2 emissions -Reduction of air pollution	-Highly cost-effective -Restructuring tax system to taxing resource use -Equity issues in providing energy services	-Major effort from industry -Change regulatory and tax systems -Coordination -International coordination and monitoring
Process Improvement -process integration -reduction non-CO_2 emission	-Voluntary Agreements -Regulatory Measures	-Savings on CO_2 and non-CO_2 GHG emissions -Reduction of air pollution	-Highly cost-effective	-Major effort from industry -See above
New Technologies and Processes - new production technologies, e.g. steel, chemicals, pulp	-RD&D -International Corporation	-Savings on CO_2 and non-CO_2 GHG emissions -Reduction of air pollution	-R&D investments -Cost-effective on the long-term -Transform industrial infrastructure and basis	-Funding -Industry, academic and government labs -Modest changes in administrative factors
Conversion				
Cogeneration - CHP using gas turbines, fuel cells	-Voluntary Agreements -Regulatory Measures -Market Mechanisms -RD&D	-Reduction in CO_2 emissions -Reduction in air pollution	-Highly cost-effective -Some industry restructuring (PPI)	-Major effort from industry -Changes in regulatory regimes -Siting for optimal use
Fuel Switching -natural gas -biomass -solar (drying, water heating)	-Regulatory Measures	-Reduction in CO_2 emissions -Reduction in air pollution	-Highly cost-effective -Internalizing external costs may hasten shift -Trade-off with other uses (e.g. biomass)	-Major effort from industry -Opposition of producers fuels being displaced
Material Use				
Efficient Material Use -efficient design -substitution -recycling -material quality cascading	-Voluntary Agreements -Market Mechanisms -Regulatory Measures -RD&D	-Reduction in CO_2 emissions -Reduction in air pollution -Reduction in solid waste and primary resource use	-Highly cost-effective -Decreased use of primary resources -Dislocations in existing industry -Job creation near product users	-Major effort from industry -Engage all actors in problem solving -Regulatory changes -Opposition to regulatory changes

Table 9.3 Summary of case studies on technology diffusion programmes and policies within countries.

Case Study	**Country**	**Technology**	**Type**				**Reference**
			Assessment	Agreement & Implementation	Evaluation & Adaptation	Repetition	
Energy Management in Metal Manufacturing Plant	Russia	Monitoring & Control	●	●	●		Avdiushin *et al.*,1997
Waste Heat Recovery & District Heating	Czech Republic	Waste Heat Recovery at Rolling Mill & Distribution	●	●	●		Marousek *et al.* 1998
Energy Conservation Audit Programme for SMEs	Japan	Energy Auditing	●				Oshima, 1998
Waste Minimisation Circles	India	Improved Operation, Maintenance and Management Practices	●		●	●	Berkel, 1998a.
Technology Information, Forecasting and Assessment Council	India	Information Collection, Assessment and Promotion on Technologies	●				TERI, 1997

Table 9.4 Summary of case studies on technology diffusion programmes and policies between countries.

Case Study	**Countries Organisation**	**Technology**	**Type**				**Reference**
			Assessment	Agreement & Implementation	Evaluation & Adaptation	Repetition	
National Cleaner Production Programme	UNIDO & various host countries	Training & Facilitation of Cleaner Production	●		●	●	Berkel, 1998b
Energy Efficiency for Large Industry as Business	Germany India	Energy Auditing & Training	●			●	Menke, 1998
COREX Smelt Reduction	Austria Korea	Advanced Ironmaking Process Technology	●	●			Joo, 1998a
Development of the FINEX Process	Austria Korea	Joint Development of new Ironmaking Process			●	●	Joo, 1998b
Pulverised Coal Injection for Blast Furnaces	USA Korea	Coal Grinding and Injection Equipment	●	●		●	Joo,1998c
Global Semiconductor Partnership	Global	Technology Development to Reduce PFC Emissions	●	●	●	●	Andersen,1998a
Vietnam Leadership Initiative	Vietnam TNCs	Technology Cooperation to Phase Out CFC Use	●	●	●		Andersen,1998b
Mexico Solvent Partnership	Mexico U.S.	Phasing out CFC use in Mexican Industry	●	●			Andersen,1998c
Dry Coke Quenching	China, Japan	Dry Coke Quenching		●			Hu *et al.*,1998